室蘭工業大学
学術資源アーカイブ
Muroran Institute of Technology Academic Resources Archive

On the Friction between Vibrating Bodies

著者	NAITO Masachika, KIKUCHI Kazuyuki
journal or publication title	Memoirs of the Muroran University of Engineering
volume	1
number	3
page range	381-388
year	1952-12-20
URL	http://hdl.handle.net/10258/3008

On the Friction between Vibrating Bodies

Masachika Naito* and Kazuyuki Kikuchi**

Abstract

The investigators have measured the frictional force between mutually vibrating bodies of the same material, and found the apparent coefficient of the kinetic friction to be decreased by the increase of amplitudes and frequencies in comparison with the coefficient of the static friction.

I. Preface

Under the stationary state of machines and structures, the parts fixed by frictional force generally keep tight. But if machines move and cause any vibration, small crevices come about on these parts. These crevices are stored up one after another, and mutual displacements or relaxations come about finally. The mechanisms or causes of relaxations are supposed in different ways, and it is supposed that one of the causes is attributed to a decrease in the frictional force between vibrating bodies.

As testing materials the same material for both sliding plates and weights were taken, because if they were not the same material, cracks would come about and could not be gotten a constant condition. As materials mild steel, brass and ebonite were taken. The vibration was horizontal, and the frictional force was measured by sliding weights with a constant speed parpendicular to the direction of the vibration. Frequencies and amplitudes were changed severally.

II. The Arrangement and Method of the Experiment

The arrangement of the experiment is summarized in Fig. 1. To get horizontal vibrations the "Piston-Crank" mechanism is used. The sliding plate is fixed to the position which corresponds to the piston part, and reciprocates through the guide. The crank radius is adjustable from zero to 40 *mm* to get any amplitude. The revolutions of the primover are changed to six steps—75, 125, 155, 175, 290, 450 r.p.m.—, and moreover speeded up by spur gears. The speed up ratio of the gears is 127/25. The range of frequancies is from zero to 38.

* 内藤正鄕　** 菊地千之

The materials of test pieces are mild steel, brass and ebonite, and the surfaces of contact are ground by the emery fine papar (000 grade). The vibrating plate is rectangular and the sliding weights are cylindrical. These dimensions are shown in Table 1.

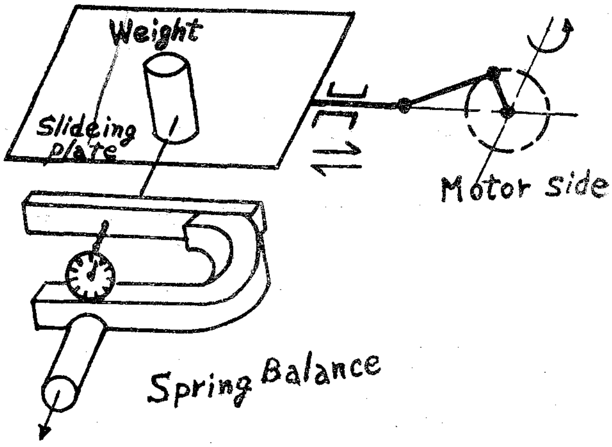

Fig. 1

For the measurement of the frictional force a spring balance with a dial indicator which was calibrated previously is used as shown in the figure. By reading the graduations of the dial gauge frictional forces are known from the calibrating curve.

In this experiment, lubricating oil is not used but the experiment is performed on a dry state. The weight of the sliding weights is changed variously.

Table 1. Dimension of Arrangement

Test Piece			Steel	Brass	Ebonite
Vibrating Plate (mm)			$155\times75\times8$	$120\times80\times5$	$140\times100\times3$
Weight Brock	Dia. (mm)		$D_1=37$ $D_0=47$	$D_1=27$ $D_0=40$	$D=40$
	Weight (gr)	No. 1	905	938	330
		No. 2	1385	1363	
		No. 3	1825		
Crank Radius (mm)			$0\sim40$		
Connecting Rod (mm)			80		
Gear Ratio			127 : 25		
Rotational Speed of Motor Side			0, 75, 125, 155, 175, 290, 450.		

III. The Results Obtained

The coefficient of the static friction should be independent of weight, but it increases slightly as the weight increases as shown in Table 2. This is supposed to be due to the roughness of the surface.

Fig. 2, 3, 4 show the relation between frequencies, frictional forces and amplitudes. If the frequency increases, the frictional force decreases and finally approaches a certain value. And as the amplitude increases, the frictional force decreases. Now we denote by μ the coefficient of the friction (Apparent friction) between vibrating bodies and take the ratio μ/μ_o, where μ_o denotes the coefficient of the static friction.

The relation between μ/μ_o, frequencies and amplitudes is shown in Fig. 5, 6, 7. Seeing from the figures, μ decreases hyperbolally against frequencies in the same amplitude. (To take one example in the case of brass, amplitude 0.1 *mm*, it is denoted by equation $\mu/\mu_o=26.4x^{-0,543}$.)

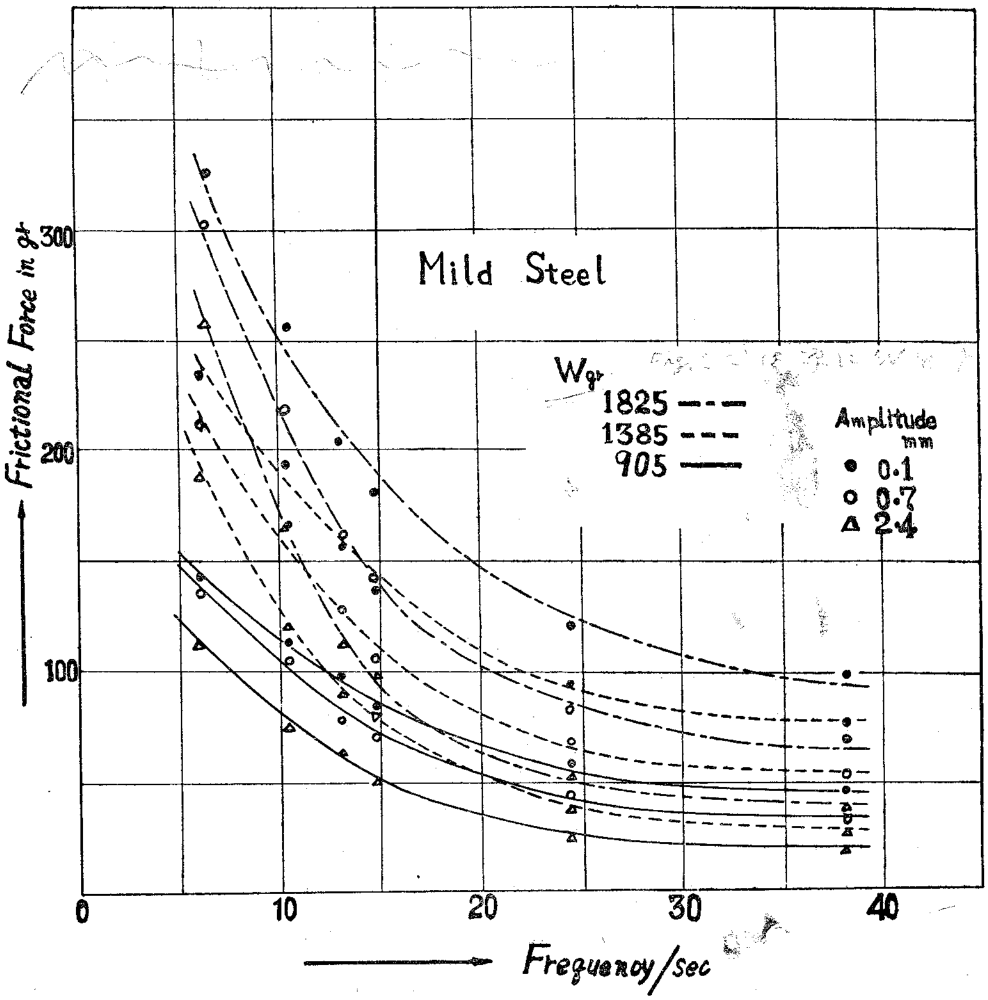

Fig. 2

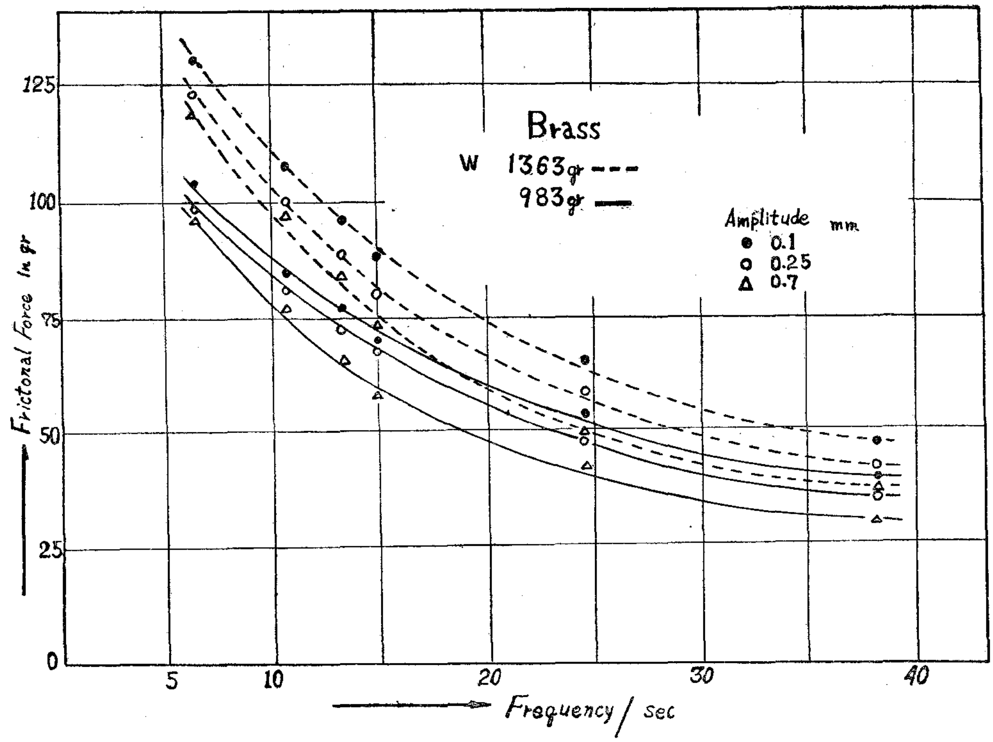
Brass
W 1363gr
983gr
Amplitude mm
0.1
0.25
0.7
Frictional Force in gr
Frequency / sec
0
25
50
75
100
125
5
10
20
30
40

Fig. 3

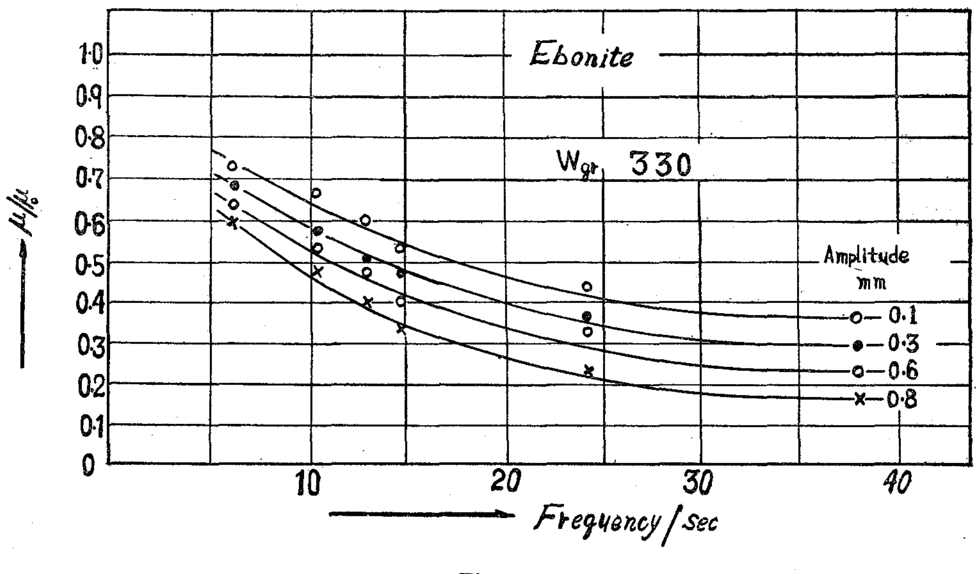
Ebonite
Wgr 330
Amplitude mm
0·1
0·3
0·6
0·8
μ/μ_0
Frequency / sec
0
0·1
0·2
0·3
0·4
0·5
0·6
0·7
0·8
0·9
1·0
10
20
30
40

Fig. 4

Table 2. Values of μ/μ_0

Material	W (gr)	Freq. / Amp. (mm)	0	6.3	10.1	13	15	24	38	μ_0
Mild Steel	905	0.1	1.0	0.87	0.69	0.59	0.60	0.36	0.23	0.19
		0.7	1.0	0.82	0.64	0.48	0.45	0.28	0.20	
		2.4	1.0	0.69	0.47	0.39	0.30	0.15	0.11	
	1384	0.1	1.0	0.86	0.71	0.59	0.50	0.35	0.28	0.20
		0.7	1.0	0.78	0.61	0.43	0.39	0.25	0.20	
		2.4	1.0	0.70	0.45	0.34	0.30	0.14	0.10	
	1825	0.1	1.0	0.86	0.68	0.54	0.48	0.32	0.26	0.21
		0.7	1.0	0.80	0.58	0.42	0.38	0.22	0.18	
		2.4	1.0	0.68	0.44	0.30	0.26	0.14	0.10	
Brass	938	0.1	1.0	0.97	0.79	0.72	0.64	0.50	0.37	0.11
		0.25	1.0	0.92	0.75	0.68	0.63	0.45	0.34	
		0.7	1.0	0.90	0.72	0.61	0.54	0.39	0.28	
	1363	0.1	1.0	0.97	0.80	0.72	0.66	0.48	0.35	0.12
		0.25	1.0	0.92	0.75	0.68	0.60	0.43	0.32	
		0.7	1.0	0.89	0.73	0.63	0.54	0.37	0.28	
Ebonite	330	0.1	1.0	0.73	0.67	0.60	0.53	0.43	0.37	0.31
		0.3	1.0	0.68	0.57	0.50	0.47	0.37	0.30	
		0.6	1.0	0.63	0.53	0.47	0.40	0.33	0.23	
		0.8	1.0	0.60	0.47	0.40	0.33	0.23	0.17	

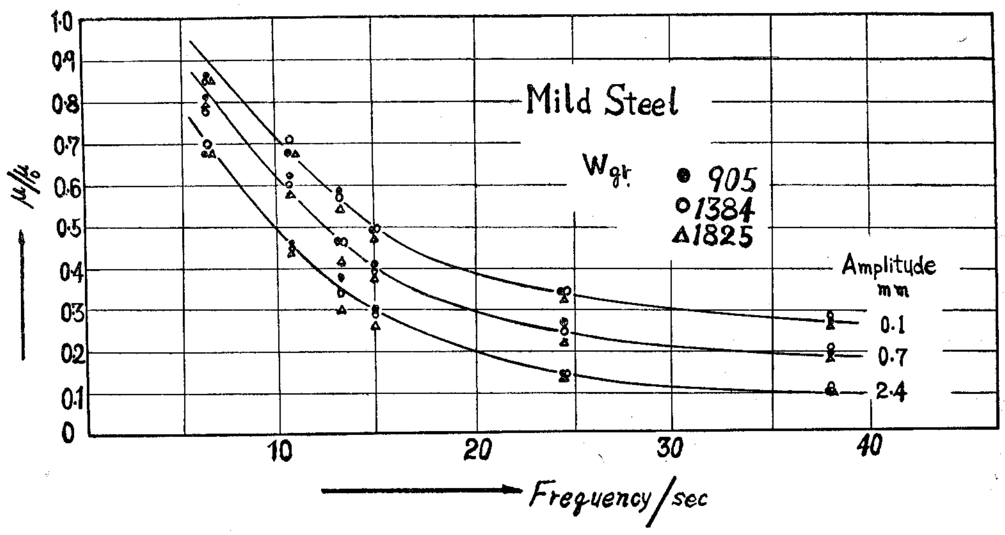

Fig. 5

As the amplitude increases μ decreases, but in this case, the effect of weight is inconsiderable. At the point (N=0) the curve does not pass the point (μ/μ_o=1). It is supposed that if the frequency does not come to a certain extent the effect does not come out.

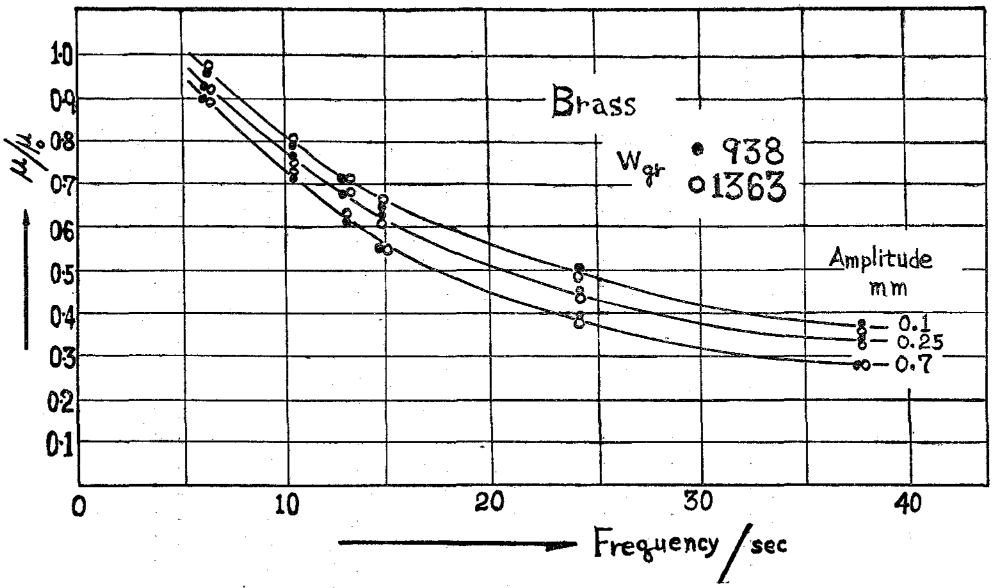
Brass
W_{gr} • 938 ○1363
Amplitude mm
0.1
0.25
0.7
μ/μ_0
1·0
0·9
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
0
10
20
30
40
Frequency /sec

Fig. 6

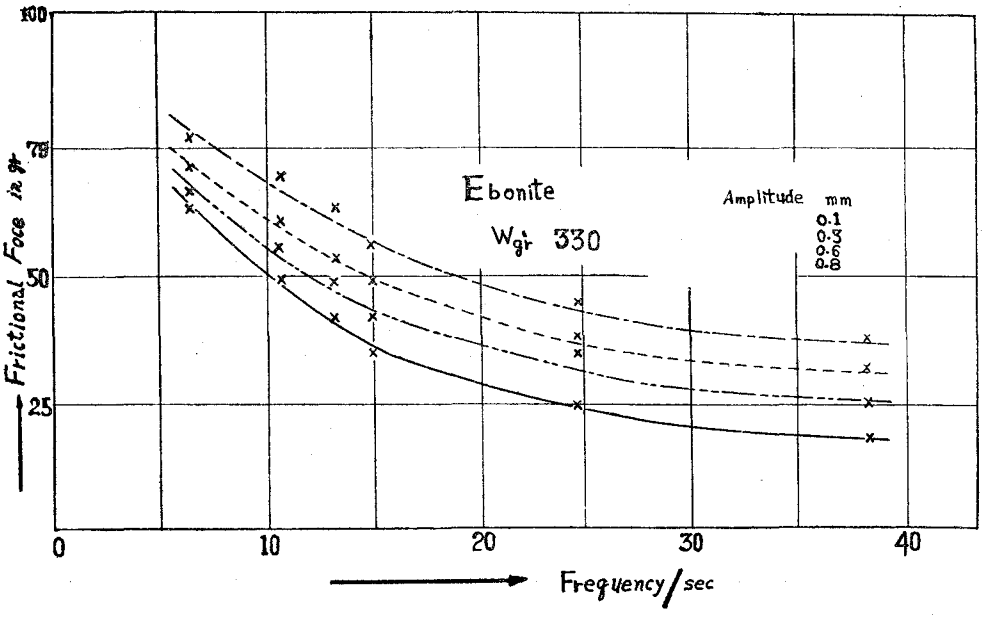
Ebonite
W_{gr} 330
Amplitude mm
0.1
0.3
0.6
0.8
Frictional Foce in gr
100
75
50
25
0
10
20
30
40
Frequency/sec

Fig. 7

Now if we take x for the direction of the vibration and y for the direction of pulling, the motion of the sliding plate and the weight is given by the following equation,

$$x = a \sin \omega t \qquad \qquad \text{(1)}$$
$$y = bt$$

where,

a, b . . . . constant

t . . . . . . time

ω . . . . . . circular frequency.

Accordingly, the locus figured on the plate by the weight is given by equation,

$$x = a \sin \frac{\omega}{b} y. \qquad \text{(c.f. Fig. 8)}$$

If we take F for spring force,

$$F = \mu W = \mu' W \frac{v_y}{\sqrt{v_x^2 + v_y^2}} \qquad \qquad \text{(2)}$$

where,

μ' . . . . . . coef. of friction for any direction

v_x . . . . . . speed for x direction

v_y . . . . . . speed for y direction

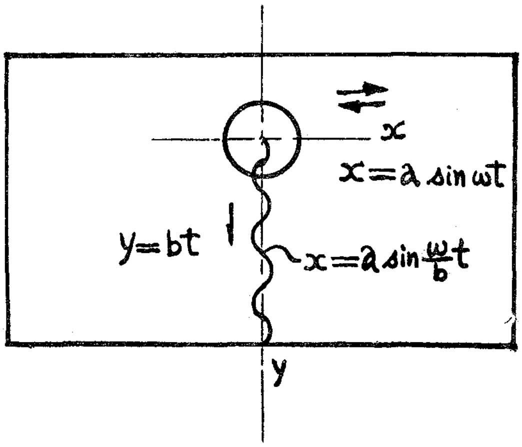

Fig. 8

From eq. (1),

$$v_x = \frac{dx}{dt} = a\omega \cos \omega t$$

$$v_y = \frac{dy}{dt} = b \qquad \text{......................(3)}$$

$$0 \leqq v_x^2 \leqq a^2\omega^2$$

As v_x^2 changes from zero to $a^2\omega^2$ (maximum) and v_y is constant, from eq. (2) frictional force F changes every moment. But actually F takes a constant value for the constant frequency and amplitude. So it is supposed to be due to the effect of maximum velocity or mean effect of motion. Accordingly, if v_y is constant, the frictional force or the apparent coefficient of the friction is decreased by the increase of frequencies or amplitudes.

IV. Conclusion

From the experiment on two kinds of metal (mild steel and brass) and one kind of non-metal (ebonite) it was found that the frictional force (parpendicular to the direction of the vibration) between mutually vibrating bodies was decreased by the increase of frequencies or amplitudes.

(Received October 31, 1950)